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FY03 DELTA Loop Corrosion Test Plan

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Test Objectives and Goal:

For FY02, the DELTA Loop test has two objectives: (1) Operation performance test for extended unmanned test operations with oxygen control. (2) Short term test of MEGAPIE window candidate materials and several variations of alloys and surface treatment.

The goal is to achieve stable test operations with oxygen control over extended period, to provide performance data for the MEGAPIE window candidate materials for one specific (slightly more stressed) condition, and to provide data to understand the protective oxide growth and repair mechanisms and kinetics.

This set of objectives and goal takes into consideration of the programmatic importance of supporting international collaboration, and performing science-based R&D for transmutation science.

Test Materials and Selection Rationale:

This first group of materials is technology/engineering oriented.

T91 (9Cr-1Mo) - Top candidate for MEGAPIE window material

T91-316L and 316L/316L weld – MEGAPIE construction

HT-9 - Well developed “nuclear-grade” steel, candidate window material and fuel cladding

316 L SS - Top candidate for LBE system in low to medium temperatures and low radiation environment

EP-823 - Special Russian alloy developed for high temperature LBE applications (fuel cladding); reference performance (we have two kinds – from IPPE, Obninsk; and from Timken Company, US, experimental heats)

Additional Materials (science oriented – to achieve better understanding of the corrosion mechanisms, kinetics, and critical factors enhancing corrosion resistance):

Ta - Impervious to LBE, performance in oxygen controlled LBE unknown (the preferable condition is perhaps oxygen-free – this test may serve as off-normal condition test for special system made of Ta)

Si-Fe - Si a key element in Russian alloys’ enhanced corrosion resistance

(For future considerations: Cr-Fe, Al-Fe)

Aluminized steels (CEA) – CEA Saclay group claimed good corrosion resistance in IPPE's loop and static LBE, and used it for CICLAD, a test loop with rotating disk test section

GESA-treated steels (FZK) – FZK claimed good test results in IPPE's loop and its own static LBE test

Alumina – this should be the form protective film for aluminized steels and GESA-treated steels

SUS 444 - low carbon, 1 (instead of 2 for 316L) wt. % Mn and 17.5-19.5% Cr and 1.75-2.5 Mo (316L has 2-3 Mo), provide comparison to 316L without Ni.

Table 1. Test Materials Matrix

Materials	Corrosion Specimens (8mm W, 35mmL, 1mm T)	Tensile Specimens (envelop dimensions: 8mm W, 35mmL, 1mm T)	Availability/Source /Time Frame
T91 (9Cr-1Mo)	4	5	Yes/Maloy/Now
HT-9 (ANL)	4	5	Yes/Li/Now
HT-9 (Timken)	4	5	Yes/Li/Now
316 L	4	5	Yes/Maloy/Now
T91-316L weld	4	5	Yes/Maloy/Now
316L-316L weld	4	5	TBD
EP-823 (IPPE)	4	5	Yes/Li/Now
EP-823 (Timken)	4	5	Yes/Li/Now
SUS 444	4	5	Yes/Maloy/Soon
Ta	4	-	Yes/Maloy/Now
Fe	4	-	Yes/MIT/Now
1.24%Si - Fe	4	-	Yes/MIT/ Now
2.55%Si - Fe	4	-	Yes/MIT/ Now
3.82%Si - Fe	4	-	Yes/MIT/ Now
Aluminized 316	5 (dimension varied)	-	Yes/CEA/Now
GESA-treated	4 (dim?)	-	Yes/FZK/?
Alumina	4	-	Yes/Maloy/Now

The specimens without special surface treatment will have #32 finish (close to 600 grit).
T91-316L TIG (or EB) weld: pre-heating to 200°C.

For corrosion specimens, there will be 2 control samples per material. For tensile specimens, there will be 4 control samples per material.

Test Conditions and Selection Rationale:

Temperature: 500°C max, 100°C gradient - more stressed than MEGAPIE (MEGAPIE T_{in} ~240, T_{out}~340, $T_{win,max}$~380°C)

Flow velocity: 2 m/s - max design limit (before onset of erosion) according to Russian experience, MEGAPIE V_{max} < 1.5 m/s

Oxygen level: 10^{-6} wt% - mid-range of oxygen control regime

Time intervals: 333, 667, 1000 hours in FY03 - determine initial oxidation kinetics while establishing stable test operations with oxygen control; 1-, 2-, 3000 hours tests show at 550°C, the oxidation kinetics dominates the first 2000 hours; for MEGAPIE, 4-, 5000 hour test sufficient; for long term corrosion behavior, tests longer than 6000 hours needed

Specimen management: two batches in for 333 h test, one batch extracted afterwards, one more added for additional 667 h test to obtain 667, 1000 h batches; may intentionally destroy (scratch/cut) the oxide from the 1000 h batch at 333 h to observed repair kinetics

Test Specimens and Selection Rationale:

Small sizes: 8mm W x 35mm L x 1mm T - accommodate more samples in tests suitable for a large scale test loop (DELTA); approximate thickness of (MEGAPIE) target windows

Miniature plate specimens: 4/mat'l/interval - sufficient for weight change, optical microscopy, SEM, TEM, XPS, EDAX and other means of characterization

Miniature tensile specimens: 5/mat'l/interval - measuring mechanical property changes after immersion, at test temperature; well established correlation in APT experiments

Control specimens: 2 corrosion plate samples per material, 4 tensile samples per material

Total numbers: corrosion specimens - (4/mat'l/interval x 3 intervals + 2 controls) x 12 mat'ls = 168 (excl. Al-316L, GESA-treated, Alumina)

Tensile specimens - (5/mat'l/interval x 3 intervals + 4 controls) x 7 mat'ls = 133

Total – 168 + 133 = 301

At any time there are two batches (for two time intervals) in the test section – (corrosion) 4/mat'l/interval x 2 intervals x 12 mat'ls + (tensil) 5/mat'l/interval x 2 intervals x 7 mat'ls = 166

Additional Specimens:

C-ring or U-bend: TBD - in-situ stress, looking for possible LME, in future experiments (this one needs significant more development in planning)

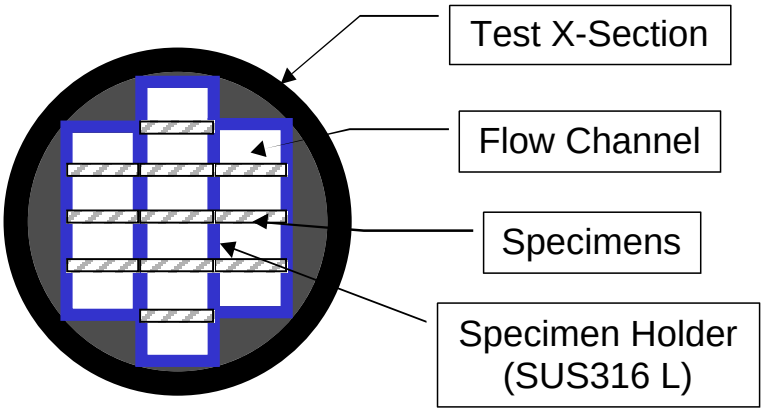
Test Configurations and Selection Rationale:

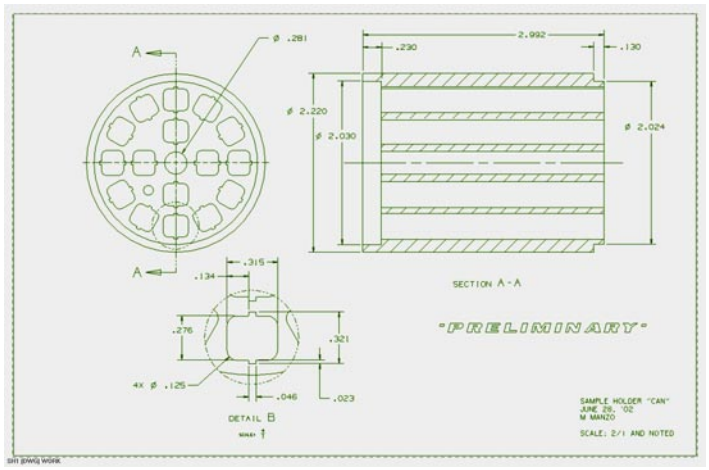
Arrangement of specimens: in lattice of uniform openings* - uniform flow distribution and conditions

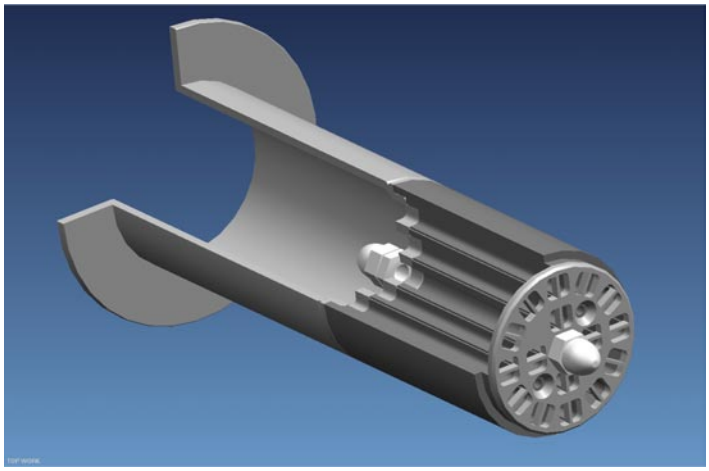
Specimen orientation: planar surface aligned streamwise - mostly cross flows in applications

Flow over specimens: after entrance length - fully developed pipe flow. To ensure this, a holder with 316 L plate samples will be installed in front of the two test sample holders to provide sufficient entrance length. These specimens will be made separately and can be analyzed for entrance flow effects on corrosion.

* Schematic layout







Post Test Examinations

Because of the large number of specimens, it is envisioned that the tested specimens be distributed to several collaborating institutions (UNLV, MIT, possibly INEEL, ANL or European organizations) for independent analysis, to be compared with LANL in-house analysis.